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A Pliocene Chalicothere from Nebraska, and the Distribution of Chalicotheres in the Late Tertiary of North America

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The present paper is a report on an early Pliocene chalicothere from north-central Nebraska and the distribution of chalicotheres in Miocene deposits of North America. Remains of these animals have been reported from Oregon, California, Nevada, Montana, Colorado, South Dakota, Nebraska, and Florida (fig. 1), but many were in scattered finds that have not been recorded from definite rock units; temporal allocations were based primarily on studies of the faunas associated with them. Few of these specimens have formal names, for they are too incomplete for proper taxonomic treatment.

Holland and Peterson (1913, pp. 378–406) reviewed the European and most of the known North American published records of chalicotheres. North American late Tertiary chalicothere material reported since 1914 is here summarized (table 1) and discussed. Certain specimens reviewed by Holland and Peterson are discussed again in the light of a better understanding of late Tertiary deposits and faunas.

In the summer of 1952 I collected a left third metacarpal of a chalicothere from the early Pliocene exposures of the Valentine Formation in northern Brown County, Nebraska (fig. 2). Paleontologically, this Valen-

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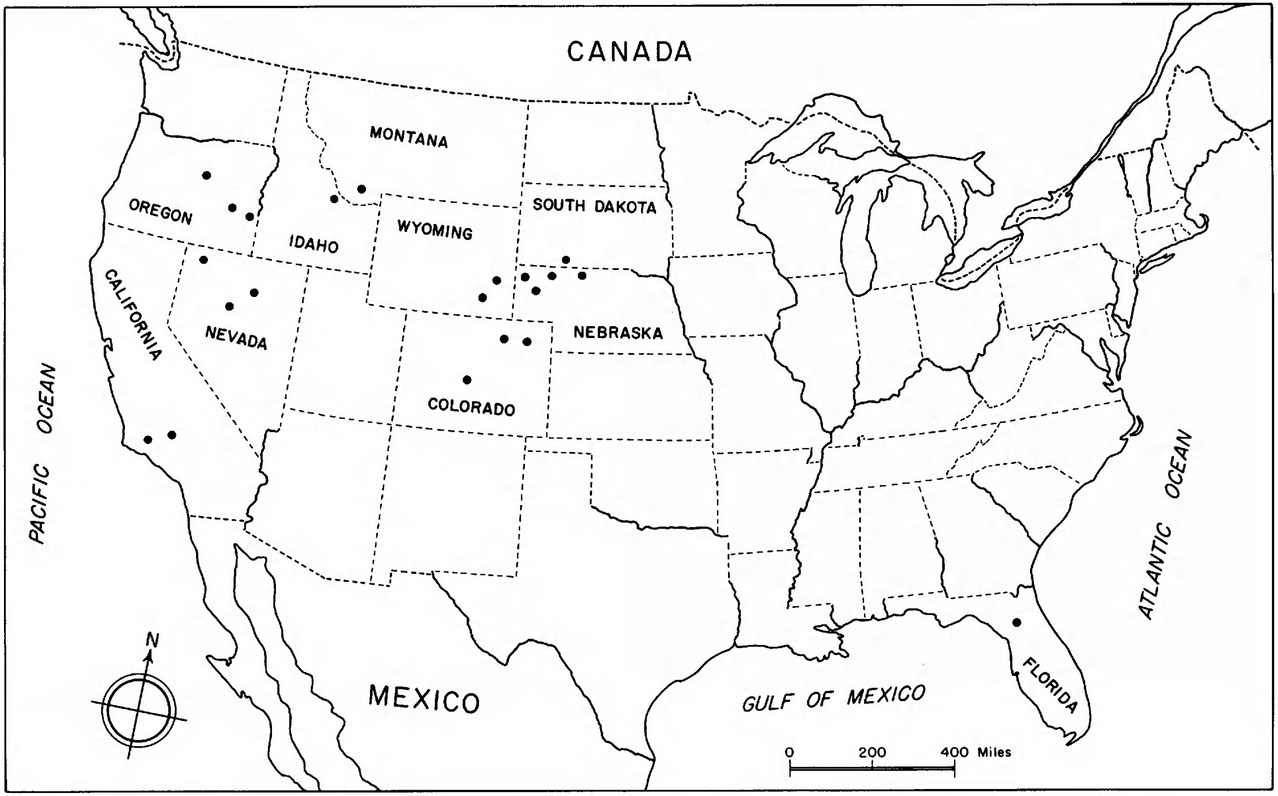

FIG. 1. Map showing localities where chalicothere remains have been found in North America.

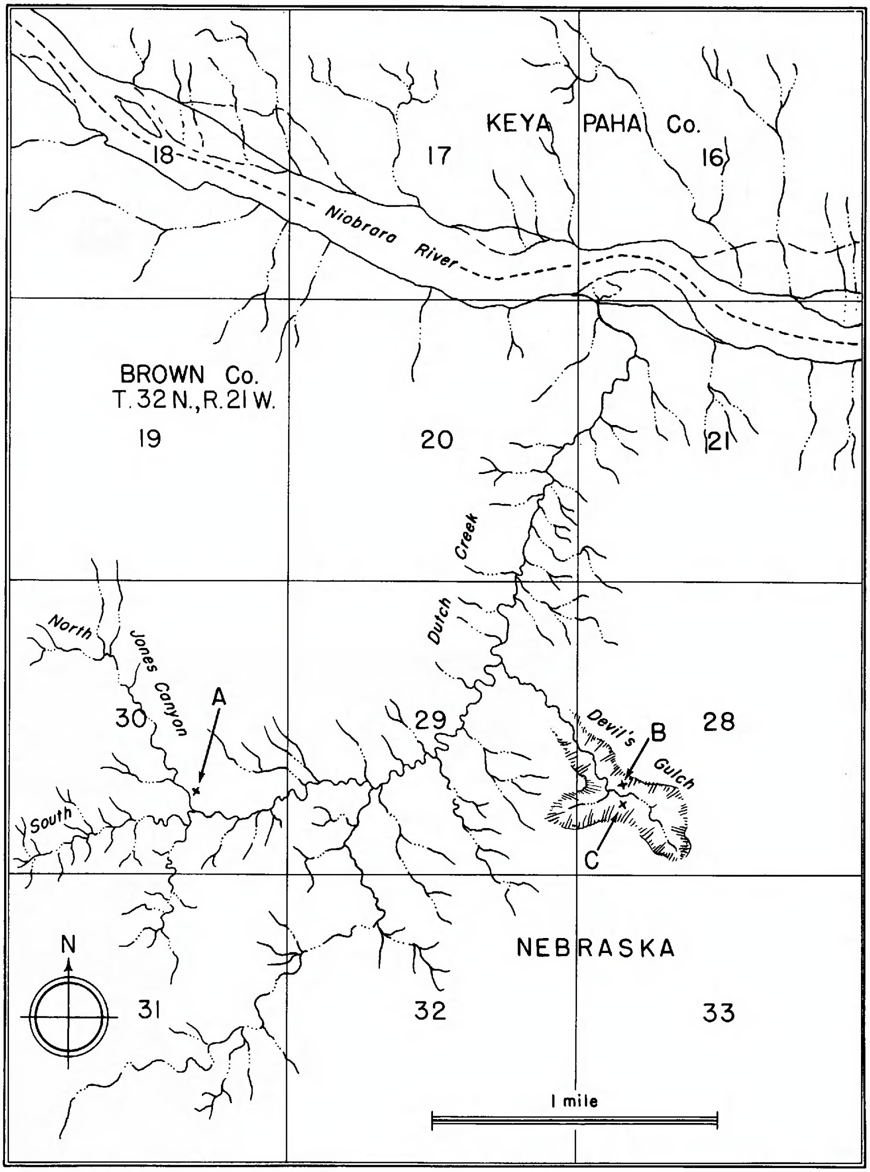

FIG. 2. Map showing the Dutch Creek drainage system in northern Brown County, Nebraska. A. Chalicothere site in Jones Canyon near the west head of Dutch Creek. B. Devil's Gulch faunal site of Barbour, 1913. C. Devil's Gulch Horse Quarry of Frick Laboratory, 1933–1934. From United States Department of Agriculture Adjustment Administration (1939), photograph numbers CAL. 2.20, CAL.23.39, CAL.2.41.

TABLE 1

DOCUMENTARY DATA FROM ORIGINAL SOURCES ON CHALICOTHERE OCCURRENCES IN NORTH AMERICA

Name	Authority	Original Material	General Area	Rock Unit	Stratigraphic Position in Rock Unit	Temporal Unit	Local Fauna
Moropus distans Marsh, 1877	Marsh, 1877	Phalanges 1 and 2, cuboid	Oregon	Not given	Not given	Miocene	Not named
Moropus senex Marsh, 1877	Marsh, 1877	Phalanx 1	Oregon	Not given	Not given	Miocene	Not named
Moropus elatus Marsh, 1877	Marsh, 1877	Foot bones, patella	Nebraska	Not given	Not given	Lower Pliocene[a]	Not named
Chalicotherium elatum?	Osborn, 1890	Partial maxilla	Nebraska	Loup Fork	Not given	Not given[b]	Not named
Chalicotherium bilobatum Cope, 1889b	Cope, 1889b, 1891	Symphysis, partial ramus, broken roots	Saskatchewan, Cypress Hills	Not given	Not given	Oligocene[c] or lower Miocene	Not named
Oreinotherium bilobatum (Cope), Russell, 1934	Russell, 1934	As above, and referred dP^2 added by Lambe, 1908[d]	As above	Cypress Hills Formation	Not given	Lower Oligocene	Cypress Hills
?*Moropus* sp.	Matthew, 1901	Metapodials and phalanx	Northeastern Colorado	Pawnee Creek Beds	Uncertain	Uncertain	Pawnee Creek
Moropus (?) sp.	Merriam, 1911	Upper and lower dentitions, phalanges, tarsals	Nevada	Virgin Valley Beds	Top of lower zone, Lower Virgin Valley Beds	Middle Miocene	Lowest mammal beds in Virgin Valley
Moropus sp.	Buwalda, 1916	Partial ramus, three premolars, one molar, all worn	California	Not named (Kinnick Formation, Buwalda, 1924)	Lower fauna in sandstone chert layers	Middle Miocene	Phillips Ranch

TABLE 1—(*Continued*)

Name	Authority	Original Material	General Area	Rock Unit	Stratigraphic Position in Rock Unit	Temporal Unit	Local Fauna
Chalicotheriidae	Matthew, 1924	Lower molar, ungual phalanx	Nebraska	Lower Sheep Creek Beds	Not given in detail	*Merychippus primus* zone; Miocene	*Merychippus primus*
Chalicotherioid	Peterson, 1928	P_4, M_1, M_2[e]	Colorado	Brown's Park Formation	About middle of Brown's Park Formation	Miocene	Not given
Chalicothere? sp.	Gazin, 1932	Lower tooth fragment[f]	Southeastern Oregon	Rocks = to Payette Formation	Not given	Miocene	Skull Spring
Moropus sp.	Scharf, 1935	M^2	Southeastern Oregon	Rocks = to Payette Formation	Not given	Miocene	Sucker Creek
?*Macrotherium matthewi*	Galbreath, 1953	Right ?P_4, damaged	Colorado	Pawnee Creek Formation	Near base of concretionary sandstones	Early Hemingfordian	Martin Canyon
Chalicothere?	James, 1963	Premolar or molar fragment	Cuyama Valley, California	Caliente Formation	Lower part of Caliente Formation	Hemingfordian?	Hidden Treasure Spring
?*Moropus* sp. indet.	Dorr and Wheeler, 1964	Distal ⅔ of metatarsal III	Southwestern Montana, Ruby River Basin	Madison Valley Formation equivalent	Surface find	Early Barstovian	Not named
Chalicothere	Patton, 1967	Foot bones[g]	North-central Florida	Not given	Not given	Early to middle Miocene	Buda
Moropus sp.	Harksen and Macdonald, 1967	Not given[h]	South Dakota	Batesland Formation	32 feet above base of Batesland Formation	Hemingfordian	Flint Hill
Chalicotheriidae	This paper	Metatarsal[i]	Central Colorado	Unnamed	Near base	?Late Miocene	Not named
Chalicothere	This paper	Metacarpal III	Nebraska	Valentine Formation	Crookston Bridge Member	Early Pliocene	Not named

TABLE 1—(*Continued*)

Name	Authority	Original Material	General Area	Rock Unit	Stratigraphic Position in Rock Unit	Temporal Unit	Local Fauna
Chalicothere	This paper	Phalanx	Idaho	Not given	Talus	Not known	Not named
Chalicothere	This paper	Two metapodials	Wyoming, Jay Em District	Marsland	Low in exposures	Early Hemingfordian	Not named
Chalicothere	This paper	Partial limbs	Chugwater area, Wyoming	Marsland	Not given	Early Hemingfordian	Not named
Chalicothere	This paper	Partial forelimb	Sweetwater, Wyoming	Not given	Not given	Late Hemingfordian	Not named

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[a] Marsh (1877, p. 251) gave no other geographic or geologic description. Holland and Peterson (1913, pp. 225, 226) published data from Marsh's file showing that the collector, H. C. Clifford, probably found the specimens near the mouth of Whistle Creek in eastern Sioux County, Nebraska. The deposits in this area may be of the Monroe Creek, Harrison, Marsland, and possibly Runningwater or Snake Creek formations.

[b] Osborn (1890, p. 99) referred to the Loup Fork of Nebraska, which included both Miocene and early Pliocene deposits.

[c] Cope (1891, p. 1) was not definite in his assignment of the "Swift Current Creek Beds" but believed that they were probably older than those of the White River. At that time the White River included both the Chadron and Brule formations.

[d] The type of *Oreinotherium bilobatum* is probably a perissodactyl, but is more likely to be a titanothere than a chalicothere. The referred dP^2 can be matched by the same tooth of a titanothere.

[e] The dentition that Peterson assigned to a chalicotherioid is that of a titanothere, *Teleodus*, and is not from Brown's Park Formation.

[f] The figure showing the fragment of a lower tooth that Gazin (1932) assigned to chalicothere ?sp. is also similar to one of *Hypohippus*.

[g] Oral communication, Thomas Patton.

[h] The Frick Collection contains one second phalanx from the Flint Hill Quarry (see p. 18, footnote 1).

[i] Oral communication, Peter Robinson.

tine occurrence is important because it extends the temporal range of the North American chalicotheres into the early Pliocene. Heretofore, the youngest, unequivocal, recorded occurrence was from the middle Miocene Sheep Creek Formation in Sioux County, Nebraska.

I use the Lyellian terms, in this case Pliocene, for the North American Tertiary, with the full understanding that they are not exactly equivalent to those of Europe. I believe that it is premature, in view of our increased knowledge of the stratigraphy and fauna of several of the Tertiary deposits of North America and the advances in radiometric dating, to attempt to allocate all faunas to the North American Mammal Ages, as proposed by Wood and others (1941). Savage (1955) has proposed some useful time-rock terms for part of the Pliocene epoch and some temporal units (North American Mammal Ages) for Pleistocene assemblages. Schultz and Stout (1961, fig. 3) supplied the term Valentinian for the earliest Pliocene, as it was also considered by Osborn (1936, fig. 274, p. 318) and Simpson (1933, p. 113). I also consider the faunas derived from the Valentine rocks as representing the earliest Pliocene of North America.

The distinction between rock relationships and biostratigraphic sequences is often obscure. I have attempted to analyze the temporal relationships of the isolated chalicothere finds in a way that distinguishes between time and rock.

ACKNOWLEDGMENTS

Drs. Malcolm C. McKenna and Richard H. Tedford have critically read the manuscript and, in the course of its preparation, have brought to my attention many of the references that aided me in establishing the distribution of the chalicotheres. I am grateful to them and to Messrs. Ted Galusha and Beryl Taylor for many constructive suggestions. Mr. Raymond J. Gooris has drawn the figures of the Valentine metacarpal and has prepared the maps and the section. Mrs. Shirley M. Skinner has been especially helpful in the study and preparation of the manuscript. For the loan of specimens I am indebted to Dr. C. R. Harington of the National Museum of Canada and Dr. Craig C. Black of the Carnegie Museum, Pittsburgh. I am also indebted to Dr. Mary R. Dawson of the Carnegie Museum, Pittsburgh, for supplying me with important field data. Mr. Beryl E. Taylor of the American Museum of Natural History has identified the camel specimens, and Mr. T. M. Stout of the University of Nebraska has furnished the rodent identifications. Dr. Peter Robinson of the University of Colorado Museum and Dr. Thomas Patton of the University of Florida have provided me

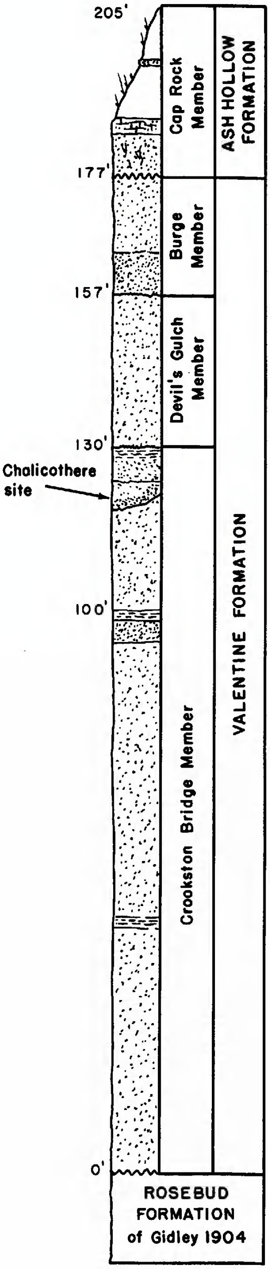

FIG. 3. Generalized rock sequence of deposits exposed near the head of the west branch of Dutch Creek in northern Brown County, Nebraska, showing the stratigraphic position of the chalicothere site.

with field and specimen data that have added to the known chalicothere distribution.

ABBREVIATIONS

C.M., Carnegie Museum, Pittsburgh, Pennsylvania
F:A.M., Frick American Mammals, Department of Vertebrate Paleontology, the American Museum of Natural History
N.M.C., National Museum of Canada, Ottawa

TABLE 2
MEASUREMENTS (IN MILLIMETERS) OF CHALICOTHERE THIRD METACARPALS FROM THE EARLY MIOCENE AND THE EARLY PLIOCENE

	Pliocene	Miocene *Moropus* Species		
		M. elatus	*M. petersoni*	*M. hollandi*
	F:A.M. No. 42982	C.M. No. 1604[a]	C.M. No. 1700[a]	C.M. No. 1424[a]
Greatest length	211.5	274	183	—
Articular length	206.2	—	—	—
Transverse proximal width	52.0	54	42	40
Transverse width, center of shaft	26.2	—	—	—
Transverse distal width	48.8	58	40	—
Anteroposterior proximal length	48.5	55	47	49
Anteroposterior length, center of shaft	29.5	—	—	—
Anteroposterior distal length	49.0	56	43	—

[a] Measurements for the Miocene metacarpals are from Holland and Peterson (1913, p. 354).

CLASS MAMMALIA

ORDER PERISSODACTYLA

FAMILY CHALICOTHERIIDAE GILL, 1872

Genus and species indeterminate

SPECIMEN: A chalicothere left third metacarpal (F:A.M. No. 42983, fig. 4, tables 1 and 2). On the basis of measurements (table 2) the Valentine metacarpal is intermediate in size between two metacarpals from the Harrison Formation in Sioux County, Nebraska, a specimen referred to *Moropus elatus* (C.M. No. 1604), and one of the syntypes of *Moropus petersoni* (C.M. No. 1700) from Carnegie Hill, Agate Springs Quarry. Holland and Peterson (1913, fig. 89) illustrated the left third metacarpal of *M. elatus* (C.M. No. 1604), which is different from the Valentine metacarpal in the size and shape of the articular facets for the magnum and unciform. The Valentine metacarpal also differs on the dorsal side and on the distal end from the metacarpal of *M. elatus.*

The Frick Collection in the American Museum of Natural History

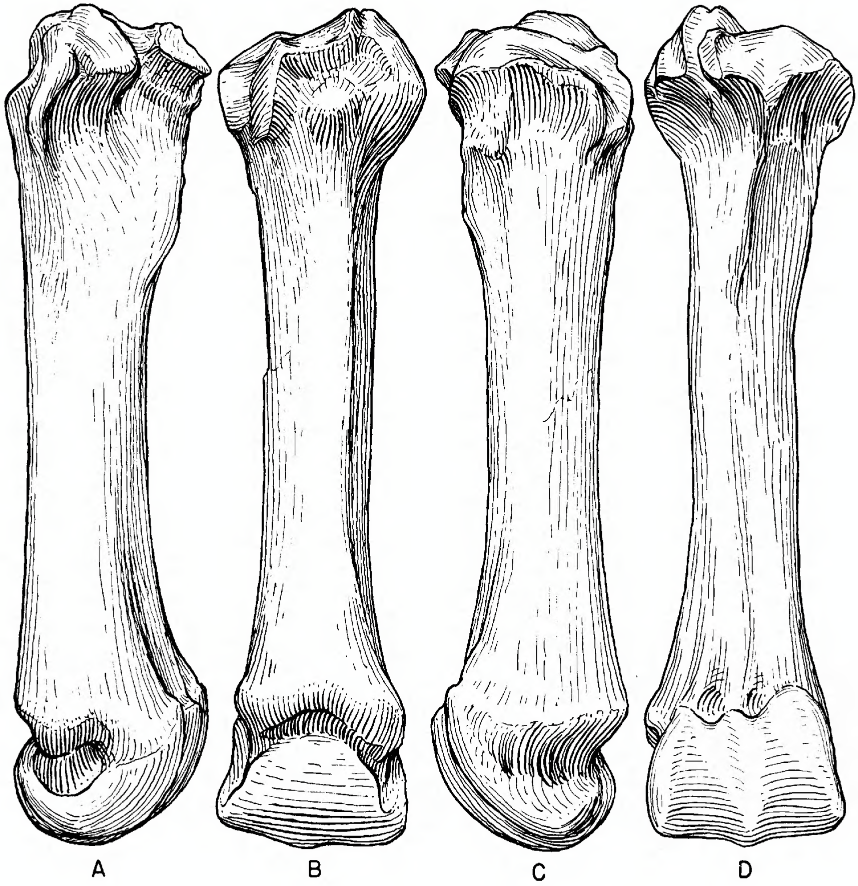

FIG. 4. Left metacarpal III, F:A.M. No. 42982, of a chalicothere from the Crookston Bridge Member of the Valentine Formation (early Pliocene) in northern Brown County, Nebraska. A. External lateral view. B. Anterior view. C. Internal lateral view. D. Posterior view. × ½.

has two additional third metacarpals from the Harrison Formation; these differ from those of *M. elatus* as well as from the Valentine specimen. A great deal of study of the Miocene Chalicotheriidae is needed before these differences can be evaluated. The Valentine metacarpal is not considered diagnostically adequate for either a generic or a specific designation. Until more evidence is available, I am referring this specimen to the family Chalicotheriidae, genus and species indeterminate.

ROCK UNIT: The Valentine metacarpal (F:A.M. No. 42983) was collected near the top of the lower part of the Valentine Formation (Crookston Bridge Member; Skinner, Skinner, and Gooris, in press), 125 feet above its contact with the Rosebud Formation (fig. 3) and just below the Devil's Gulch Member (Skinner, Skinner, and Gooris, in press) of the Valentine Formation. The stratigraphic position of the faunal site and the absence of any older deposits from the Dutch Creek drainage system and nearby areas that could have been the source of a reworked specimen indicate that the metacarpal belonged to an animal that lived contemporaneously with the other Pliocene forms found with it.

ASSOCIATED FAUNA: The channel deposit that contained the chalicothere metacarpal also had representatives of the following forms: *Eucastor tortus, "Eucastor"* species, proboscidean dentition and tusk fragments, detached teeth referable to *Pliohippus* sp., *Pseudhipparion retrusum* (formerly *Hippotherium* Cope, 1889, pp. 446–447), *"Hipparion"* sp., along with several unallocated equid limb elements. Also present were *Ustatochoerus* sp., *Homocamelus* cf. *caninus,* and *Procamelus* sp.

HISTORICAL REVIEW

Table 1

The immigration of the chalicotheres from the Old World in early Miocene time into fossil-bearing areas of the United States is suggested by their sudden appearance in abundance at such Harrison Formation sites as Agate Springs Quarry. The upper part of these deposits is dated radiometrically as not older than 21.3×10^6 years on the evidence supplied by the analysis of a volcanic ash (KA 481) by Evernden, Savage, Curtis, and James (1964, p. 178). This ash occurs 30 feet below the level of the Agate Springs Quarry in Sioux County, Nebraska.

With the exception of the Late Arikareean accumulation in the Harrison Formation at the Agate Springs Quarry in Nebraska, recorded occurrences of the Chalicotheriidae in North America are rare in the Neogene. Wood and others (1941, pp. 11, 12) included the chalicothere genus *Moropus* among the taxa that first appeared in North America in Arikareean time but did not mention the last appearance of this genus or its family. The scarity or absence of chalicotheres in post-Arikareean deposits has long been a mystery; almost every occurrence has been the subject of a published notice. No undisputed evidence of chalicotheres has yet been reported from fossil-bearing deposits of earlier Miocene or Oligocene age in the United States.

In Canada, however, *Chalicotherium bilobatum* was described by Cope (1891, pl. 4, figs. 1–1b) from lower Oligocene deposits in the Cypress Hills. Cope's species was based on a symphysis with a fragmentary, toothless, left ramus, showing the alveoli for P_2–M_1. In a review of the Cypress Hills fossil vertebrates, Lambe (1908, p. 55, pl. 3, figs. 7–9) tentatively referred a left deciduous P_2 to *Chalicotherium bilobatum,* concluding at the same time that "The Cypress Hills species needs to be studied from better material before its true generic affinity can be determined." Holland and Peterson (1913, p. 218) designated *C. bilobatum incertae sedis* and noted further that the dentition did not represent a chalicotherioid.

In a subsequent revision of the fauna, Russell (1934, pp. 62–64) erected the genus *Oreinotherium* for Cope's species *bilobatum* on the grounds that the mandibular fragment showed similarities to the European genus *Macrotherium* (= *Chalicotherium*[1]), in the dental formula and in the depth of the mandible. Russell wrote, "the much later geological age of *Chalicotherium* [as then understood] renders it unlikely that the present species [*O. bilobatum*] pertains to that genus."

I have examined the type of *O. bilobatum* and the deciduous P_2 later reported by Lambe. These two specimens are all that is known of Russell's genus *Oreinotherium.* Although Russell (1934, p. 63) gave generic characters based on the tooth and mandibular fragment (N.M.C. No. 6468), I believe that this genus and species should be regarded as a *nomen inquirendum* as well as *incertae sedis.* The deciduous P_2 (N.M.C. No. 6469) is closely similar to a milk premolar of a titanothere and displays no characters that allow assignment to any specific brontothere genus. Therefore, the presence of the Chalicotheriidae in the Oligocene Cypress Hills is doubtful. The name *Oreinotherium* probably applies to one of the brontothere genera from those deposits.

Merriam and Sinclair (1907, p. 186) included the Chalicotheriidae (*Moropus distans* Marsh and *Moropus senex* Marsh) in the total fauna from the John Day region, Oregon. A generalized stratigraphic sequence in a later section of the same publication (pp. 187–192) indicated that the total fauna was divided into "lower, middle, and upper John Day Divisions," but chalicothere remains were not included in any of these faunas. Wood and his co-authors (1941, p. 22) placed the John Day faunas as no younger than Arikareean and no older than Whitneyan.

The specimens on which Marsh based his two species of *Moropus, M. distans* and *M. senex,* have no stratigraphic data so far as is known. The specimens may have been derived from the John Day Formation, or the Mascall Formation, or even from the Rattlesnake Formation, since all three are in the John Day basin. Downs (1956, p. 323) presented a Mascall faunal list in which he selected comparable Miocene faunas from Oregon, California, and Nevada. The Chalicotheriidae were not included in the Mascall fauna, but did appear in the Skull Spring, Virgin Valley, Sucker Creek, Stewart Springs, and High Rock Canyon faunas.

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[1] *Macrotherium* is now synonymized with *Chalicotherium,* following Butler (1965).

Gazin (1932, pp. 80, 81, fig. 13) reported an incomplete lower molar (U.S.N.M. No. 348) of a "Chalicothere ? sp." in the Skull Spring fauna from deposits in southeastern Oregon, but gave no record of the relative stratigraphic position of the specimen, except that it was included as an element of a supposedly contemporaneous fauna. The fragmentary and well-worn lower molar is inconclusive evidence of the presence of a chalicothere. The specimen might also represent the equid *Hypohippus,* which was an identified component of the Skull Spring fauna.

Gazin described the Skull Spring fauna as medial Miocene in age, or slightly later. He also correlated the deposits containing the Skull Spring fauna with the Payette Formation of adjacent Idaho. The rocks containing the Skull Spring fauna are now referred to the Butte Creek Volcanic Sandstone of Kittleman and his co-authors (1965, pp. 15, 16). In regard to the age of this formation, these authors wrote: "The Butte Creek Volcanic Sandstone contains Barstovian (late Miocene) mammalian fossils of the Skull Springs fauna . . . and of the Red Ridge Basin fauna. . . . A potassium-argon determination of sanidine from the rock in the Red Ridge Basin fossil quarry gave an age of 15.1 m.y. (Evernden and others, 1964, p. 190, sample KA 1029)." This is slightly older than the so-called Sheep Creek ash from Sioux County, Nebraska, which was dated by Evernden, Savage, Curtis, and James (1964, p. 181, KA, 891) at 14.7×10^6 years.

Another southeastern Oregon faunal site was reported by Scharf (1935). From the flora, Scharf (1935, p. 99) inferred that the deposits containing the Sucker Creek fauna were directly related in age to the Payette Formation and noted that future study might prove that the Sucker Creek deposits are an integral part of the Payette Formation. Scharf concluded that the Sucker Creek deposits were Miocene but specified no definite part. Chaney (*in* Chaney and Axelrod, 1959, p. 114) observed certain lithologic differences between the Sucker Creek deposits and the Payette Formation to the north, which he believed might represent a different facies of the Payette Formation, but agreed with Scharf that the stratigraphic position of the Sucker Creek deposits and the Payette Formation was similar.

In 1965 Kittleman and his co-authors published a detailed and comprehensive study of the stratigraphy of the Owyhee region in Oregon.

Those authors gave the name "Sucker Creek Formation" to some 590 feet of measured beds at the type section and stated, "Assignment of the Sucker Creek Formation to the late Miocene is based upon Barstovian mammalian fossils of the Sucker Creek fauna collected near the type locality."

Buwalda (1916, p. 79) reported the occurrence of *Moropus* species as one of the constituents of the Phillips Ranch fauna from deposits in the Tehachapi Pass region of southern California. In 1934 Buwalda defined and named these deposits the Kinnick Formation. Wood and others (1941, p. 28) allocated the Phillips Ranch local fauna to the Hemingfordian. Evernden, Savage, Curtis, and James (1964) dated an ash (KA 478), from below the deposits carrying the Phillips Ranch fauna, at 17.1×10^6 years and placed it in Late Hemingfordian. The chalicothere specimen that Buwalda (1916, p. 79) assigned to *Moropus* was "a portion of a lower jaw containing three premolars and a molar, all little worn."

James (1963, pp. 13, 139) recorded "a fragment of an upper premolar or first molar of a perissodactyl, questionably designated as a small chalicothere" in the Hidden Treasure Spring fauna from the Caliente Formation, Cuyama Valley Badlands, southwestern California. According to James, exposures of the Caliente Formation have yielded mammalian faunas that range in age from medial Miocene to medial Pliocene. James assigned a Hemingfordian age to deposits carrying the Hidden Treasure Spring fauna, which is from the Caliente Formation, 50 feet above the contact with the unconformably underlying Plush Ranch Formation. Associated with the questionable chalicothere upper cheek tooth are *Merychippus carrizoensis, Parahippus* sp., *Hypolagus vetus,* and *Ticholeptus calimontanus.*

Localities in Virgin Valley, High Rock Canyon, and Little High Rock Canyon, Humboldt County, in northwestern Nevada, were the source of identified remains of chalicotheres. Merriam (1911, pp. 267–271, figs. 39–45) presented adequate proof of Chalicotheriidae (*Moropus* sp. indet.) from "the lower fossil-bearing horizon in Virgin Valley and High Rock Cañon." No representatives of the Chalicotheriidae were found from the upper fossiliferous zones in Virgin Valley or from the Thousand Creek area. Based on the presence of *Moropus,* a *Thinohyus*-like form, and the absence of *Pliohippus,* Merriam (1911, p. 208) assigned the Virgin Valley fauna to medial Miocene. The Virgin Valley fauna is now generally assigned to the Barstovian or transitional Hemingfordian-Barstovian. Downs (1956, pp. 322, 323) suggested a "close chronologic and faunal resemblance between the Virgin Valley and the Skull Spring."

Stirton (1939, pp. 627–633) noted that chalicothere remains were found near Stewart Spring at the north end of Stewart Valley, Esmeralda County, Nevada. Because no further mention was made as to the identity of the specimen (or specimens), the occurrence of a chalicothere at Stewart Spring is not included in table 1 of this paper. Wood and others (1941, p. 32) placed the Stewart Spring fauna in the Barstovian.

The Upper Ruby River Basin in the extreme southwestern part of Montana is the source of late Tertiary fossil vertebrates. Dorr and Wheeler (1964) have dealt thoroughly with the stratigraphy and vertebrate paleontology of the area. In 1948 C. W. Hibbard collected a partial third metatarsal of a chalicothere from beds that Dorr and Wheeler (1964, pp. 307, 325) believed were equivalent to the Madison Valley Formation. The chalicothere metatarsal was derived from their Locality 5. Regarding the age of the fauna, these authors wrote (p. 320), "The mammalian faunule from Locality 5 clearly is Barstovian in age; moreover, it probably is early Barstovian."

Matthew (1901, pp. 358, 359) reported chalicothere remains in a faunal list of specimens from his Pawnee Creek beds[1] in northeastern Colorado. Matthew's discussion of the stratigraphic occurrence of "*?Moropus* sp." is difficult to understand and reflects his uncertainty about the level from which the chalicothere specimens were collected. Matthew (1901, p. 358) wrote that chalicothere remains were derived from the base of his Pawnee Creek beds, and, on the following page, that the specimens might also have been derived from the higher fossil-bearing zone, which he then equated with the Ogallala Formation.

Galbreath (1953, pp. 106–107) expressed doubt about Matthew's allocation of the chalicothere remains to the upper part of the Pawnee Creek beds and suggested that Matthew's chalicothere specimens had probably been derived from earlier beds. Galbreath (1953, p. 107) referred his own chalicothere specimen (a damaged P_4) to his Martin Canyon local fauna from deposits in the lower part of his Pawnee Creek Formation and concluded, "However, the absence of chalicotheres from the lower Snake Creek fauna, which has many forms in common with the Pawnee Creek fauna, is suggestive that they occur in the Martin Canyon fauna but not the Pawnee Creek fauna[1] in northeastern Colorado." Galbreath should have considered the Nevada and Oregon occurrences that had been correlated previously with Lower Snake Creek faunas of Nebraska.

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[1] Although the same area is involved, Matthew's (1901) "Pawnee Creek beds" are not to be confused with Galbreath's (1953, p. 18, fig. 8) "Pawnee Creek Formation." Matthew defined his Pawnee Creek beds by their contained fauna; rocks apparently were secondary, and Galbreath was justifiably confused by Matthew's terminology. I treat Galbreath's (1953) Pawnee Creek Formation as a set of distinct lithic units. It is not possible to interpret Matthew's "Pawnee Creek beds" in this manner.

About 10 years after Matthew's 1924 report on the Sioux County faunas, Frick Laboratory field parties discovered chalicothere remains in channel deposits that produce Lower Snake Creek faunas. The rocks from which these Lower Snake Creek faunas have been derived are not to be considered as a part of the Sheep Creek Formation as later expanded by Lugn (1938) and Elias (1942). McKenna (1965, pp. 10–15) has explored this problem. The faunas from Matthew's Lower Snake Creek beds are distinctly Barstovian and are separated from the Sheep Creek faunas by an extended erosional and temporal hiatus.[2]

The Frick Collection contains numerous (at least 50) examples of chalicotheres, as yet undescribed, from quarries within the type Sheep Creek beds ("rocks") as originally designated by Matthew and Cook (1909). The faunas from these rocks are considered to be late Hemingfordian.

Matthew, in his later reports, apparently changed his mind about correlating the Ogallala Formation with his Pawnee Creek beds. Moreover, he changed his concept of the faunal relationships, particularly in regard to the chalicothere examples from the Pawnee Creek beds. The following statements show Matthew's later interpretation of the Pawnee Creek beds and also reflect the attitude then prevalent toward stratigraphic classification and nomenclature. In earlier geologic terminology, in North America at least, the necessity for treating rocks and faunas as separate entities had not been clearly appreciated. Matthew, as well as others, often used rocks and faunas interchangeably, so that the exact meaning was not always expressed.

In an initial report on the Snake Creek beds in western Nebraska, Matthew and Cook (1909, p. 362) stated, ". . . the Sheep Creek beds . . . appear to correspond in age to the Pawnee Creek beds of Colorado, the

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[1] Galbreath (1953, pp. 34, 35, fig. 8) defined the "Pawnee Creek fauna of authors" as limited to the Eubanks, Kennesaw, and Vim-Peetz local faunas. He excluded the Martin Canyon local fauna (early Hemingfordian) and the Sand Canyon local fauna (early Clarendonian) from the general Pawnee Creek fauna, which he believed was correlated in time with the Barstovian.

[2] This statement is based on my stratigraphic and faunal studies made in conjunction with fossil collecting in Sioux County from 1941 to 1947. I have restudied this area periodically up to the present (1968). This is the same area reported upon by Matthew and Cook (1909), by Matthew, (1918, 1924, and 1932), and by Sinclair (1915).

Deep River of Montana and the Mascall of Oregon." In 1918 Matthew (p. 183) wrote, "From the older Sheep Creek beds were obtained a number of skeletons of *Merychippus* . . . all indicating an early phase of the *Merychippus* zone equivalent to or slightly older than the Pawnee Creek beds of Colorado." In 1924 Matthew (pp. 71, 72) presented a list of the fauna from the Lower Snake Creek beds in correlation with a list of the fauna from the Pawnee Creek beds, in which he made no mention of the presence of chalicotheres. In the same paper Matthew (pp. 152, 153) stated: "A lower molar and ungual phalanx serve to prove the existence of a chalicothere in the Lower Sheep Creek beds. . . . No chalicotheres have been recognized in the Lower Snake Creek beds [in reference to rocks], although they occur in the contemporary Pawnee Creek of Colorado (*'M.' matthewi*) and Virgin Valley of Nevada (*'M.' merriami*). Whether the family survived into the Pliocene in North America is doubtful. . . . It has not been recognized in any of the later collections from known Pliocene horizons."

In Brown's Park in northwestern Colorado chalicothere remains were believed to have been present. Peterson (1928, p. 110) reported that a chalicotherioid dentition collected "approximately in the middle of the vertical section of the sedimentary mass referred to the Brown's Park Formation . . . is of unusual interest, because it is among the first recorded specimens from the true Brown's Park Formation of the Uinta Mountains, and greatly assists in the determination of the geological age of this sedimentary mass." An examination of some of the specimens that Peterson recorded as having been derived from the Brown's Park Formation indicates that a re-evaluation of this area is needed.

The chalicotherioid dentition (C.M. No. 11392) cited by Peterson as an aid in his allocation of the Brown's Park Formation to the Miocene consists of fragmentary lower cheek teeth that have now been identified as *Teleodus,* species indeterminate. The catalogue data with the specimen state: "Duchesne River, La Point Horizon, Oligocene, near Vernal Utah."

A written communication from Dr. Peter Robinson (January, 1968) gives notice of a metatarsal, referred to the family Chalicotheriidae, that was collected in southwestern Park County, central Colorado. On the basis of the associated fauna, a component of which was identified as *Mylagaulus laevis,* Robinson estimated the age of the deposits as ?late Miocene.

The Loup Fork of Nebraska was cited by Osborn (1890, pp. 99, 100) as the source of a partial maxilla of *"Chalicotherium elatum?"* in the Garman Collection at Yale. Osborn gave no stratigraphic data. Without them the Loup Fork assignment has little significance, for deposits ranging in age from Miocene to Pliocene were included under this term at that time.

Harksen and Macdonald (1967, pp. 9, 10), in the description of their new Batesland Formation (Miocene) in southwestern South Dakota, listed *Moropus* sp., as part of the fauna. These authors cited the "Flint Hill Quarry"[1] of the University of California as the primary source of vertebrate fossils from the Batesland Formation, and they assigned their new formation to the Hemingfordian on biostratigraphic evidence.

Patton (1967, p. 8) reported chalicothere remains from near Newberry, Alachua County, in north-central Florida. In a written communication Patton (1968) identified the remains as a metapodial, ungual phalanx, and fused phalanges (second and third). Patton further stated that the fossils were part of the Buda Local Fauna, collected from a solution cavity on top of the Ocala Limestone, and that the age of the fauna could be from early to medial Miocene. Associated with the chalicothere were remains of a large carnivore and a large oreodont.

In addition to the foregoing published reports of the chalicothere occurrences in North America the Frick Collection has examples from Idaho and Wyoming (table 1). A phalanx, unmistakably that of a chalicothere, was collected at the upper end of the Lemhi River Valley, about 46 miles southeast of the town of Salmon, Idaho. The specimen, weathered and coated with lichen, was recovered from the talus. Oreodonts collected in the same area were referred to *Merychyus arenarum idahoensis* by Schultz and Falkenbach (1947, pp. 186, 187). These authors have considered the age of the deposits from which *M. arenarum idahoensis* was derived to be biostratigraphically equivalent to the Marsland Formation of the Great Plains.

Three different collecting areas in Wyoming have produced chalicothere remains.

Two chalicothere metapodials were collected from the Jay Em District, Goshen County, east-central Wyoming. Field data for these specimens stated simply "low down," in reference to the lower part of the exposures at a site that is 1½ miles west of the town of Jay Em. Associated in the same general area with these metapodials are examples of *Merychyus minimus* which, according to Schultz and Falkenbach (1947, p. 204), show that the deposits are biostratigraphically equivalent to the

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[1] The Frick Collection contains one second phalanx of a chalicothere that I collected from the weathered face of the Flint Hill Quarry in 1961.

Marsland Formation, Sioux County, Nebraska.

A portion of a chalicothere ulna, an astragalus, the distal end of a radius and ulna, and two phalanges were collected from exposures 7 miles southeast of Chugwater, Platte County, southeastern Wyoming. *Merychyus minimus* examples were also found in association with these chalicothere remains. Schultz and Falkenbach (1947, pp. 204, 220, 221) considered the deposits in the area, "5–8 Mi. S.E. of Chugwater," from which the chalicothere was collected, to be biostratigraphically equivalent to the Marsland Formation.

Most of a forelimb of a chalicothere was found about 7 miles west of Muddy Gap, Fremont County, Wyoming. This specimen was collected with *Brachycrus sweetwaterensis* (according to Schultz and Falkenbach, 1940, p. 251) from "Exposure No. 2 . . . [which] is divided into three small localities, namely, a, b, and c. These three outcrops extend consecutively from northeast to southwest for nearly a mile and are separated from each other by grass-covered areas. Exposures 2a and 2b have produced examples of *B. vaughani,* and No. 2c, *B. sweetwaterensis.* Here again no definite association of these two species has been established." Schultz and Falkenbach (1940, p. 220) recognized *Brachycrus* only in Miocene deposits and stated that the genus is best represented from beds in the Hemingford group in Sioux County, Nebraska (e.g., Sheep Creek and Lower Snake Creek). I infer from these statements that the age of the deposits in "Exposures No. 2" is either late Hemingfordian or early Barstovian.

CONCLUSIONS

The presently mentioned early Pliocene record from north-central Nebraska extends the temporal range of the Chalicotherioidea in North America. Moreover, this Pliocene chalicothere occurrence points up the fact that this group is not restricted to either a late Arikareean or a Hemingfordian age. In the Neogene, chalicothere remains have been recovered from North American rocks ranging in age from the uppermost part of the Harrison Formation (early Miocene) to the early Pliocene (e.g., Crookston Bridge Member of the Valentine Formation; Skinner, Skinner, and Gooris, in press).

In view of the widespread late Tertiary deployment of the chalicotheres in time and space, it seems reasonable to expect that more complete examples will be found. Except for the Agate Springs Quarry in western Nebraska, where chalicothere material was found in abundance, occurrences are exceedingly and unaccountably rare. These strange, sickle-clawed perissodactyls may have had a preference for a special environment where chances for entombment were poor.

The presence of chalicotheres in deposits of early Pliocene age could be accounted for in several ways: (1) the specimen may represent a survivor of a lineage established by the first Miocene migrants from Asia; or (2) the specimen may have been a survivor of an invasion of North America that occurred in Sheep Creek or Lower Snake Creek times, when other evidence of faunal exchange exists; or (3) the specimen may represent a migration during early Pliocene time that came from Asia with the first wave of proboscideans.

The mystery of the absence of chalicotheres during Oligocene time still is unsolved. In a recent revision of Eocene chalicotheres, including the North American eomoropids, Radinsky (1964, p. 24) reasoned, "Thus from the available evidence it appears that chalicotheriids arose in Asia at the end of the Eocene, spread to Europe in the Oligocene but did not reach North America until the Miocene."

The vast period of time between the last known occurrence of Paleogene forms in North America and the earliest Miocene forms suggests that the chalicotheres became extinct in North America and later repopulated the New World from Eurasia. The paleontological evidence that would clearly demonstrate the morphological relationships of the various known Neogene examples is still lacking.

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